A Study of Stratospheric Chlorine Partitioning in the Winter Polar Vortices Based on New Satellite Measurements and Modeling

Aura Science Team Meeting

10 November 2005

M.L. Santee[1], I.A. MacKenzie[2], G.L. Manney[1,3], N.J. Livesey[1], L. Froidevaux[1], W.G. Read[1], J.W. Waters[1], P.F. Bernath[4], R. Nassar[4], K.A. Walker[4], C.D. Boone[4], M.P. Chipperfield[5]

[1]Jet Propulsion Laboratory, California Institute of Technology, USA
[2]University of Edinburgh, UK
[3]New Mexico Institute of Mining and Technology, NM, USA
[4]University of Waterloo, Canada
[5]University of Leeds, UK

Introduction

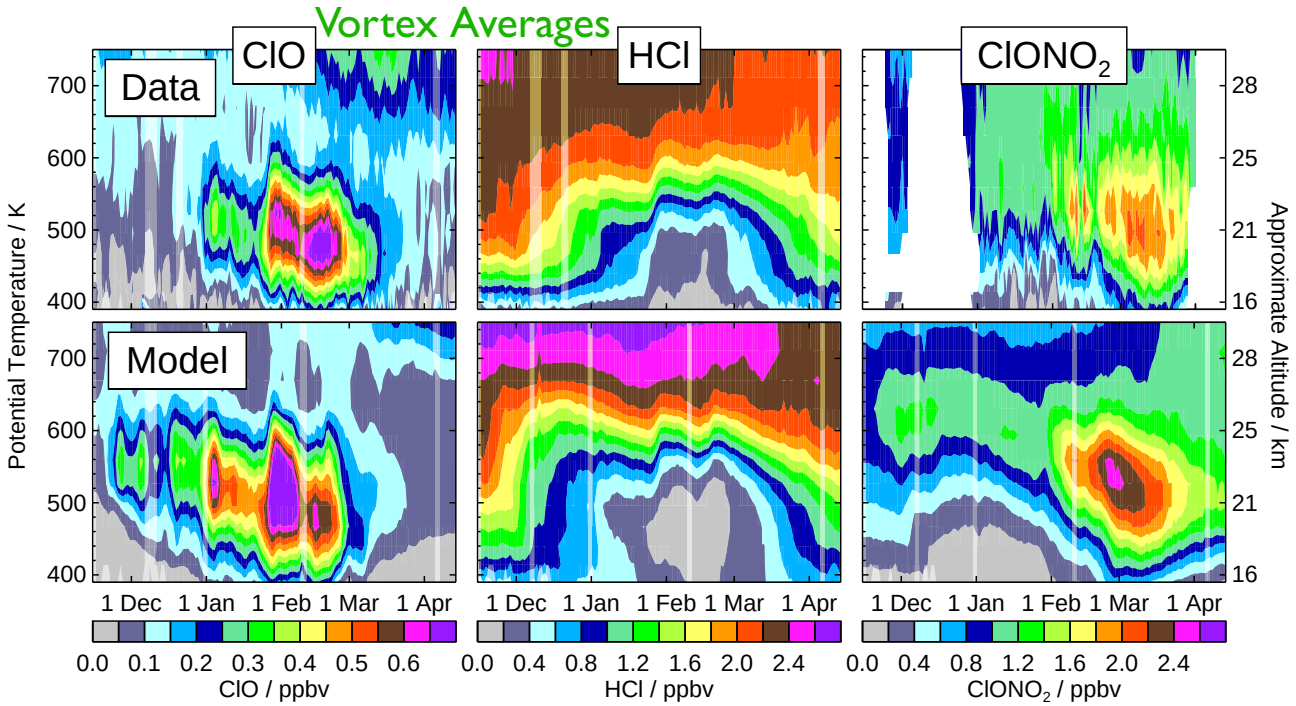
- Two recent satellite instruments provide measurements of unprecedented scope for investigating chlorine partitioning in the winter polar vortices

- The Microwave Limb Sounder (MLS) on Aura measures several key species involved in stratospheric ozone chemistry, including the first simultaneous daily global profiles of HCl and ClO
- MLS data are now available for an entire winter season in both the northern and southern hemispheres

- The Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS) on the Canadian SCISAT-1 mission provides solar occultation profiles of a large number of species, including HCl and $ClONO_2$

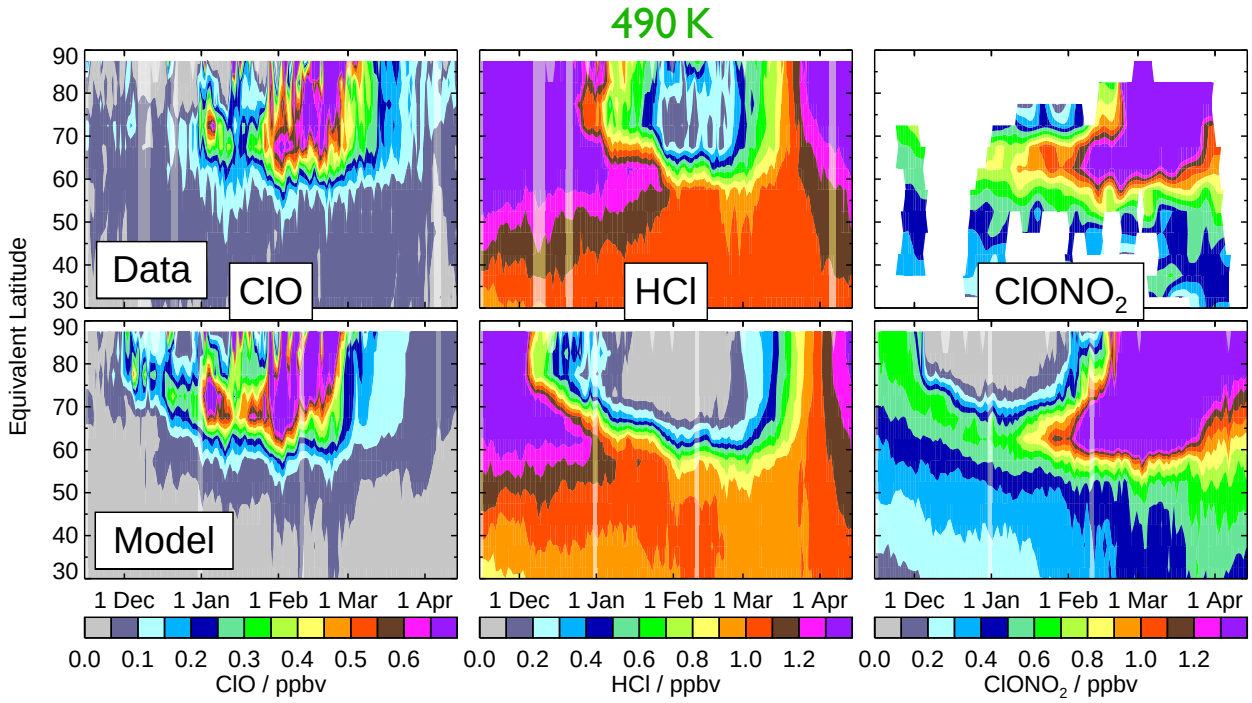
- We use MLS and ACE measurements to investigate the evolution of reactive and reservoir chlorine species throughout the lower stratosphere during the exceptionally cold 2004–2005 Arctic winter
- The satellite measurements are compared to near real time runs of the SLIMCAT 3D chemical transport model, sampled at the same location and local time as the MLS measurements
- Similar measurement/model comparisons are also made for the 2005 Antarctic winter, and inter-hemispheric differences in chlorine activation and deactivation processes are being studied

Overview of Chlorine Partitioning During the 2004-2005 Arctic Winter

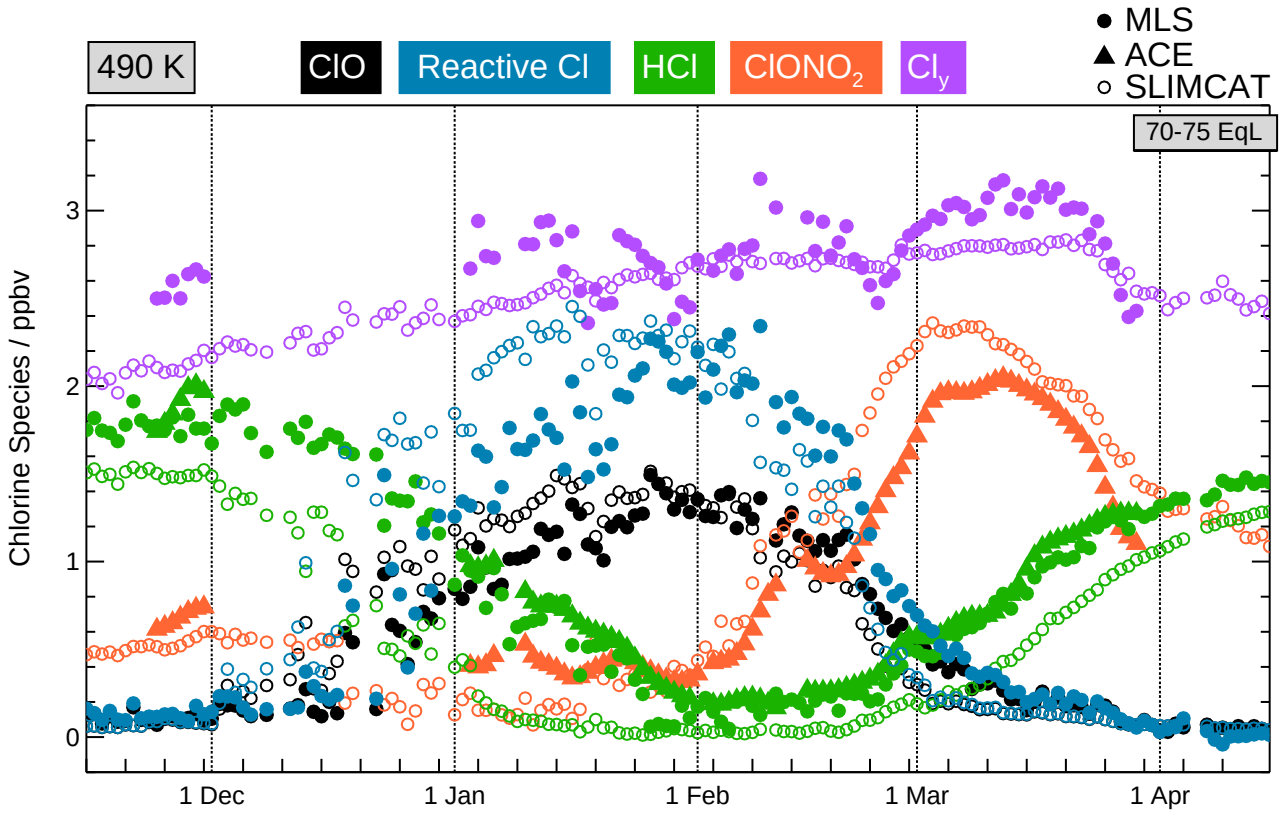


- Model and measurements are broadly consistent, but significant differences are seen throughout the winter
- Chlorine activation (ClO enhancement, HCl depletion) extends over a larger vertical range in the model than in the MLS data
- SLIMCAT shows higher $ClONO_2$ abundances in mid/late winter during initial recovery phase than ACE

- MLS measurements indicate significant chlorine activation beginning in mid-December, but SLIMCAT indicates much earlier chemical processing
- At the end of winter, both model and measurements show that substantial recovery into $ClONO_2$ occurs by early February, whereas HCl does not increase significantly until early March



Detailed Examination of 2004-2005 Arctic Winter Chlorine Partitioning

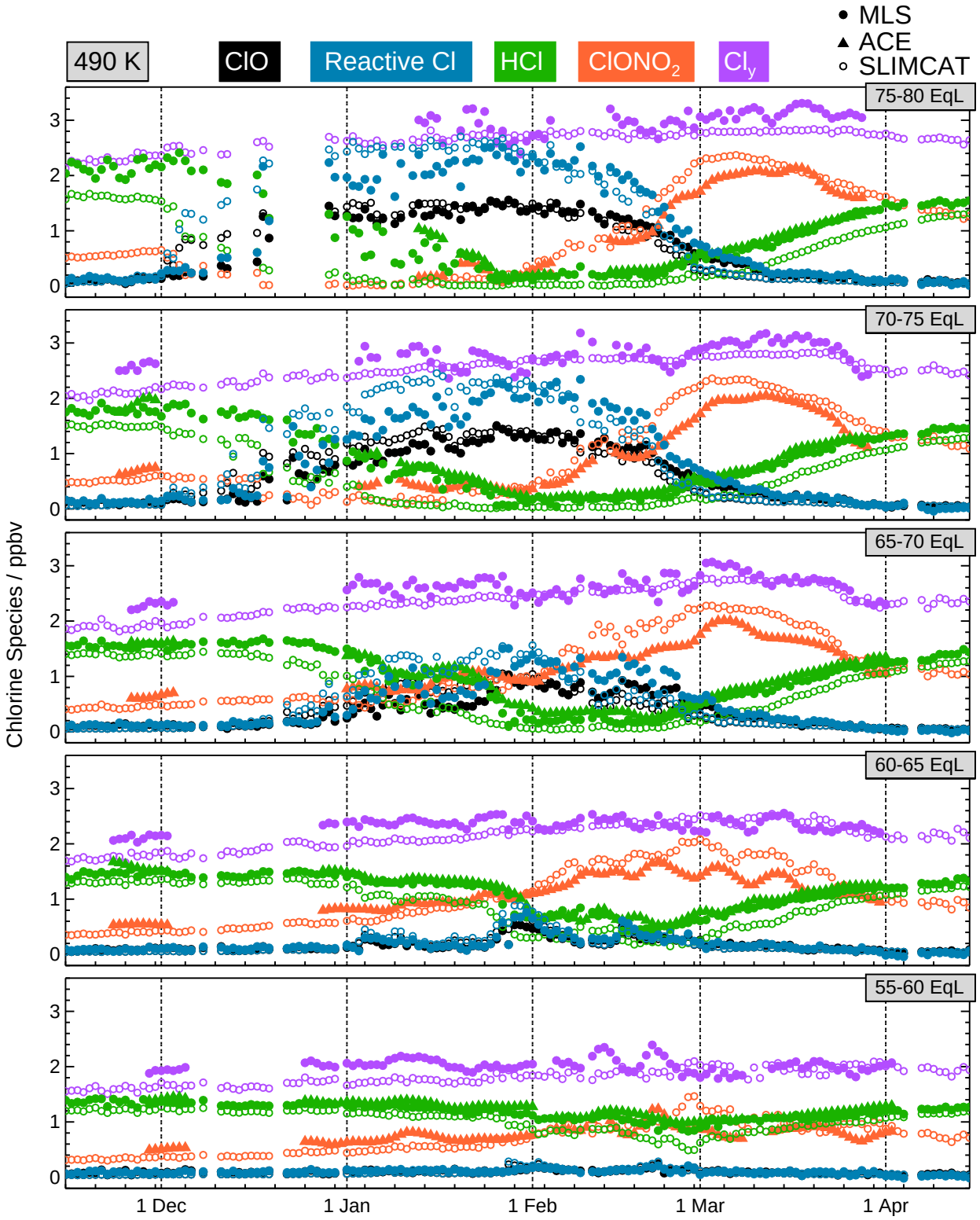


- Daily averages of MLS ClO & HCl and ACE HCl & $ClONO_2$ in 5° equivalent latitude (EqL) bands are compared with SLIMCAT
- Reactive Cl (ClO + $2Cl_2O_2$) inferred from MLS ClO data and Cl_y (Reactive Cl + HCl + $ClONO_2$) are also compared with SLIMCAT
- The exact same points are included in both MLS and SLIMCAT averages

- ACE averages do not cover the same air masses, but excellent agreement between ACE and MLS HCl throughout the winter lends confidence in the representativeness of the ACE averages
- SLIMCAT calculates more chlorine activation in early winter, overestimating reactive chlorine and underestimating HCl and $ClONO_2$ compared to measurements
- Active chlorine peaks in late January/early February, when MLS/ACE and SLIMCAT agree well
- Enhanced reactive chlorine persists slightly longer in the data than in the model
- Both model and measurements show initial deactivation into $ClONO_2$ starting in early February, whereas HCl does not begin to increase significantly until late February/early March
- Although these results generally support the canonical picture of chlorine deactivation in the Arctic, SLIMCAT overestimates the role of $ClONO_2$ and underestimates the role of HCl

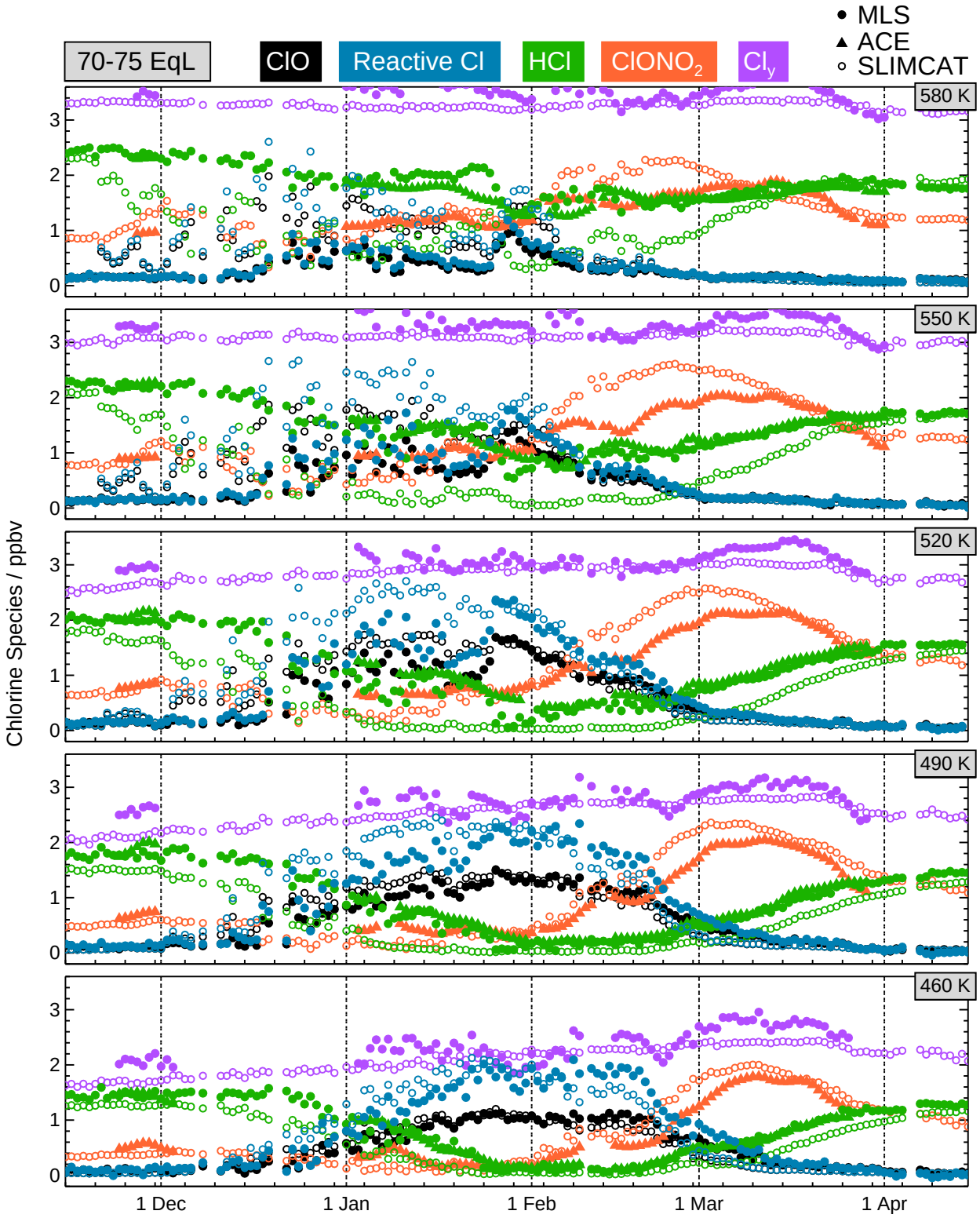
Variation with Equivalent Latitude (EqL) at 490 K

- Significant chlorine activation occurs poleward of 60–65°N EqL
- Chlorine becomes activated earlier at higher EqLs
- The early-winter discrepancy between measured and modeled active chlorine is worse at higher EqLs, where Reactive Cl values are larger
- A similar picture of chlorine deactivation is obtained at all latitudes throughout the vortex



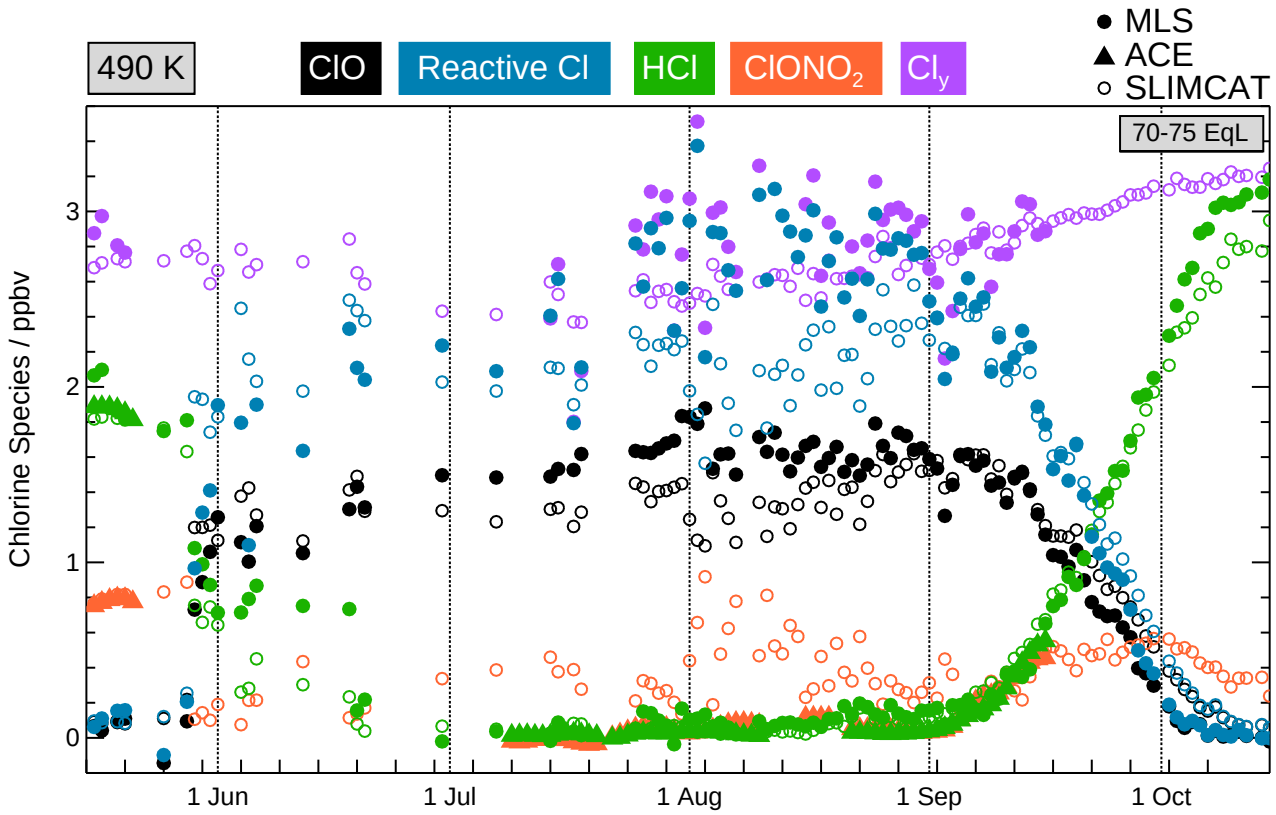
Variation with Potential Temperature at 70–75°N

- Chlorine activation extends to higher potential temperatures in SLIMCAT than in the MLS data, and the early-winter discrepancy between measured and modeled active chlorine is worse higher up
- Activation and deactivation occur earlier at higher potential temperatures; deactivation is underway by late January at 580 and 520 K but not until mid/late February at 490 and 460 K
- A similar picture of chlorine deactivation is obtained at all altitudes



Summary

- Aura MLS and ACE measurements have been examined together with results from the SLIMCAT 3D CTM to study chlorine partitioning in the 2004–2005 Arctic winter polar vortex
- At the end of the winter in the Arctic, reactive chlorine is initially converted into $ClONO_2$, which begins to increase significantly throughout the lower stratospheric vortex at least several weeks before HCl
- Although these results generally confirm the canonical picture of chlorine deactivation in the Arctic, SLIMCAT overestimates the role of $ClONO_2$ and underestimates the role of HCl



2005 Antarctic Winter

- Similar comparisons for the 2005 winter in the Antarctic, where very low ozone mixing ratios promote the preferential reformation of HCl, indicate better agreement between modeled and measured chlorine deactivation